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EVALUATION OF METABOLIC SYNDROME RISK FACTORS IN FEMALE STUDENTS

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Many studies have shown that systolic and diastolic arterial blood pressure changes due to higher weight in both school-age children and in adolescents. Abnormalities of thyroid function might be no less important factor in relation to metabolic syndrome. The objective of the study was to determine the relationship of arterial blood pressure, glucose, adiponectin and thyroid function parameters to major risk factors of metabolic syndrome. The risk factors tested were body mass index (BMI) and waist circumference in female students aged 18 to 25 years. We studied 105 RSU Red Cross college students aged 18 to 25 years. We calculated their BMI, lung vital capacity (ml), thyroid changes by ultrasound (USG) (27 students) and ECG (79 students). In addition, we measured their waist and chest circumferences, and systolic and diastolic blood pressure in both arms. We determined concentration of glucose, adiponectin, thyroid stimulating hormone (TSH) and free thyroxine (FT4) in blood. Statistical analyses were performed using the SPSS 15.01 package software. There was a statistically significant positive correlation between the arterial blood pressure, BMI and increase of the waist circumference in students (average age 20.7 years). The average arterial blood pressure in students was normal. The age at the onset of menarche had a significant positive effect on diastolic arterial blood pressure ($P = 0.009–0,017$). An increase in blood glucose concentration was closely associated with BMI ($P = 0.03$) and waist circumference ($P = 0.045$). However, adiponectin concentration was correlated with systolic ($P = 0.007–0.048$) and diastolic ($P = 0.002–0.003$) blood pressure. Significant ECG changes were found in 10% of the subjects, indicating cardiovascular changes in these young women. The higher the FT4 and TSH concentrations, the more frequently were observed changes in the ECG ST-segment ($P = 0.01–0,008$). A significant relationship between diastolic blood pressure and the age at onset of menarche ($P = 0.009–0.017$) was found. Increased arterial blood pressure was associated with an increase in BMI, waist circumference and adiponectin concentration, while an increase in blood glucose concentration was associated with increased BMI and waist circumference, but not with the adiponectin level. Changes in ECG and increased diastolic arterial blood pressure in relation to menarche indicate a possible role of the endocrine system and genetic factors in regulation of the main parameters of metabolic syndrome.

Key words: *metabolic syndrome, systolic arterial blood pressure, diastolic arterial blood pressure, thyroid gland, thyroid stimulating hormone, free thyroxin.*

INTRODUCTION

In many of the world's developed countries, the number of overweight and obese young people is increasing (Ogden *et al*., 2006). Observations show that 1.1 billion adults are overweight (312 million of them are obese) and 155 million children are overweight or obese (Hossain *et al*., 2007). Approximately 18 million of the people in the world suffering from diabetes and hypertension die each year from cardiovascular diseases (Hossain *et al*., 2007). Prospective studies (19) have proven that overweight, obesity and increased mortality are strongly linked. All-cause mortality is lower when body mass index (BMI) is 20.0–24.9 (De Gonzalez *et al*., 2010).

The term 'metabolic syndrome' was first used in 1988 (Reaven, 1988). It combines cardiovascular risk factors and diabetes. Since then, the concept of metabolic syndrome has been updated, its etiological factors are being investigated, and the possible pathogenic mechanisms and guidelines are being developed. The main risk factor for metabolic syndrome is overweight and obesity (particularly abdominal), which are the main criteria of metabolic syndrome in the classification developed by the International Diabetes Federation in 2005 (Alberti *et al.*, 2005).

Metabolic syndrome is diagnosed more frequently in obese adults (50% of cases) (Weiss *et al.*, 2004). The place where the fat or "ectopic" fat accumulates is important. The pathophysiological condition called "adiposopathy" (Bays, 2009) is characterised by adipocyte hypertrophy, increased size of adipose tissue and accumulation of ectopic fat (visceral fat). This contributes to the development of cardiovascular diseases and type 2 *diabetes mellitus*, as well as to a rise in systolic and diastolic arterial blood pressure. Hypertension is the main risk factor for cardiovascular disease (Ferrannini *et al.*, 2008; Wilson *et al.*, 2008).

The pathological mechanism of metabolic syndrome is still not clear. Metabolic syndrome combines the main risk factors for cardiovascular diseases and type 2 diabetes mellitus — central adiposity, insulin resistance, glucose intolerance, dyslipidemia and hypertension. Fat is considered an endocrine organ, which promotes hormonal and bioactive substance function. One of these bioactive substances is an adipokine, whose role in the pathogenesis of metabolic syndrome is very high (Kadowaki *et al.*, 2006; Hopkins *et al.*, 2007; Rahmouni *et al.*, 2008). Hypertension is a worldwide health problem and the basic symptom of metabolic syndrome (Grundy *et al.*, 2005). There are only a few studies in the literature which have examined the risk factors for a rise in arterial blood pressure caused by BMI, waist circumference and other risk factors of metabolic syndrome in young persons 18 to 25 years of age (Must *et al.*, 1992; Lawlor *et al.*, 2006). This prompted us to study visceral obesity, hypertension and glucose intolerance in young people, with the goal of adding knowledge on means of prevention of metabolic syndrome (Ekelund *et al.*, 2009).

MATERIALS AND METHODS

Between 2007 and 2009, in the study we included 105 female students, aged 18–25, from the Red Cross Medical College. We used 15 variables in data processing, and took into account student permanent residence in one of the four regions of Latvia. We calculated their BMI, abdominal circumference, lung vital capacity (ml), thyroid changes by ultrasound (USG) (27 students) and ECG (79 students). In addition, we measured their waist and chest circumferences, and systolic and diastolic blood pressure in both arms. We determined the concentration of glucose, adiponectin, thyroid stimulating hormone (TSH) and free thyroxine (FT4) in blood. Statistical analysis of the data was performed using the SPSS 15.01 package software. To determine significant relationships we used the Pearson's, Spearman's Rho and Kendall tau- b correlation coefficients.

RESULTS

The average systolic blood pressure (SBP) was normal (113.54 ± 1.26 mmHg) with a tendency to increase with BMI and waist circumference (Table 1).

SBP was higher in students with II degree of obesity (134.67 ± 12.39 mmHg). SBP was related not only to BMI (P = 0.002–0.0012), but also with waist circumference (P = 0.002–0.021) (Fig. 1.1 and 1.2). Diastolic blood pressure (DBP) on average was normal (73.57 ± 1.1 mmHg) (see Table 1).

In the group with II degree of obesity, DBP significantly differed (93.67 ± 16.05 mmHg) in three students from the others. A significant correlation was observed between DBP and BMI level (P = 0.007), waist circumference (P = 0.009) (Fig. 2.1 and 2.2) and hip circumference (P = 0.008) (Fig. 2.3). A significant correlation was also observed between DBP and age at onset of menarche. DBP was higher (P = 0.009–0.017) when menarche began at a younger age (Fig. 2.4).

A significant relationship was observed between lung vital capacity and the level of BMI (P = 0.013–0.032) (Fig. 3.1) and waist circumference (P = 0.016–0.031) (Fig. 3.2).

ECG changes were found in 33% of cases (26 of 79 students). 10% of cases had non-specific ST-segment and T-wave changes. These ECG changes were associated with increased waist circumference (P = 0.016–0.017) but not with BMI (Fig. 4.1).

Glucose, adiponectin, TSH (thyroid stimulating hormone) and free thyroxine (FT4) concentrations are shown in Table 2. Blood glucose levels were normal, with a mean value 4.57 ± 0.05 mmol/L (see Table 2). With increasing BMI (P = 0.031) and waist circumference (P = 0.045), the concentration of blood glucose also increased (Fig. 5.1–5.2).

Adiponectin was determined in 38 students, and on average, was within the normal range with a mean value 29.45 ± 1.29 mg/ml. There is significant increase in adiponectin with increase of SBP and DBP. The correlation was stronger with DBP (P = 0.002–0.003), but less with SBP (P = 0.007–0.048) (see Fig. 6.1 and 6.2).

Ultrasonography detected thyroid nodules in three of the 27 students examined. These students were from the Kurzeme and Vidzeme region (Table 1). The average TSH and free thyroxine levels were within the normal range (Table 2). With increase in thyroxine concentration, ECG ST-segment changes were rarely observed (Fig. 7.1 and 7.2). Lung vital capacity increased with a decrease of free thyroxine concentration (P = 0.0001) (Fig. 7.3).

DISCUSSION

The key feature of the metabolic syndrome is obesity, which is evaluated by BMI, waist circumference (abdominal obesity) (Bruce *et al.*, 2009; De Gonzalez *et al.*, 2010). Obesity contributes to insulin resistance in tissues, dyslipidemia, glucose intolerance, and to adipocitokin secretion, and hypertension (Chiarelli *et al.*, 2008; Steinberger *et al.*, 2009). Hypertension and glucose intolerance are major factors for cardiovascular diseases and diabetes mellitus, which

Table 1

MEASURES OF VARIABLES IN RELATION TO BMI (systolic and diastolic arterial tension, pulse, USG, ECG, vital capacity)

BMI degrees	Statistical descriptives	BMI, kg/m^2	Waist circumference, cm	Systolic arterial tension in the right arm, mm Hg	Dyastolic arterial tension in the right arm, mm Hg	Pulse rate per minute	USG result; 0, normal = 1	ECG result; 0, normal = 5	Vital capacity, mL
Total	Number of girls	105	105	105	105	105	27	79	105
	Mean	22.7080	74.452	113.54	73.57	76.48	.33	3.61	2947.90
	SEM	.40696	1.0192	1.264	1.099	1.094	.092	.254	54.714
	Minimum	17.51	59.0	90	50	50	0	0	1300
	Maximum	39.55	114.0	157	114	115	1	5	4500
16.500–18.499	Number of girls	11	11	11	11	11	3	10	11
	Mean	17.9291	66.500	105.64	71.27	72.91	.67	3.50	2972.73
	SEM	.10299	1.3568	4.110	3.287	3.386	.333	.764	208.933
	Minimum	17.51	62.0	92	50	55	0	0	1800
	Maximum	18.44	77.0	139	85	98	1	5	4500
18.500–24.999	Number of girls	70	70	70	70	70	12	52	70
	Mean	21.3390	70.957	113.44	72.64	76.91	.25	3.65	2839.00
	SEM	.19033	.7373	1.373	1.253	1.353	.131	.311	60.503
	Minimum	18.83	59.0	90	50	50	0	0	1300
	Maximum	24.82	85.0	157	99	115	1	5	4500
25.000–29.999	Number of girls	18	18	18	18	18	9	11	18
	Mean	27.1967	84.111	114.72	75.06	75.61	.33	3.64	3250.00
	SEM	.37755	1.5401	2.432	1.921	2.715	.167	.704	148.467
	Minimum	24.97	74.0	100	60	53	0	0	2200
	Maximum	29.94	98.0	135	85	94	1	5	4200
30.000–34.999	Number of girls	3	3	3	3	3	1	3	3
	Mean	30.4867	96.000	116.67	74.67	79.00	1.00	3.33	3400.00
	SEM	.10682	4.5826	16.707	7.860	3.512	*	1.667	100.000
	Minimum	30.30	90.0	98	64	72	1	0	3200
	Maximum	30.67	105.0	150	90	83	1	5	3500
35.000–39.999	Number of girls	3	3	3	3	3	2	3	3
	Mean	37.4633	105.667	134.67	93.67	82.00	.00	3.33	3133.33
	SEM	1.22142	4.4096	12.387	16.045	7.638	.000	1.667	185.592
	Minimum	35.32	99.0	110	62	72	0	0	2900
	Maximum	39.55	114.0	149	114	97	0	5	3500

SEM, Standard Error of the Mean

have significant roles in the pathogenesis of the metabolic syndrome (Després *et al*., 2008).

Systolic and diastolic blood pressure. In our study the average arterial pressure (SBP and DBP) was normal. A rise in SBP and DBP was closely associated with increase in BMI and waist circumference. SBP changes were mainly related with BMI level and waist circumference, while DBP was also related with other factors, such as hip circumference. This indicates that gender and the endocrine system may have an effect on the DBP changes in young women (Veldhuis *et al*., 2005). Increase in BMI in school-age boys was associated with a significant increase in DBP (Ligere *et al*., 2001; 2002; Madrevica *et al*., 2002). As demonstrated in our previous study, an increase in BMI and the waist circumference in school-age girls was observed together with a rise in SBP (Ligere *et al*., 2001). This suggests that different factors cause changes in DBP and that these factors should be closely examined. In our study, DBP changed in students who had their first menarche prematurely. An earlier first menarche was associated with a higher DBP. There are almost no research articles that describe this association in the literature. It is mentioned in the literature that Spanish girls with premature adrenarche and insulin resistance are lean (Ibáñez *et al*., 2000). In our study, arterial pressure was above normal in three students with the II degree of obesity and 106.7 cm waist circumference. SBP, unlike DBP, does not change depending on hip circumference and the age at onset of menarche. This indicates a role of the endocrine system and genetic factors in the overall pathogenesis of the metabolic syndrome.

Vital capacity. As our studies show, vital capacity significantly increases with increased BMI and waist circumference. It should be mentioned that three students with the II degree of obesity and increased waist circumference (106.7

Systolic arterial tension

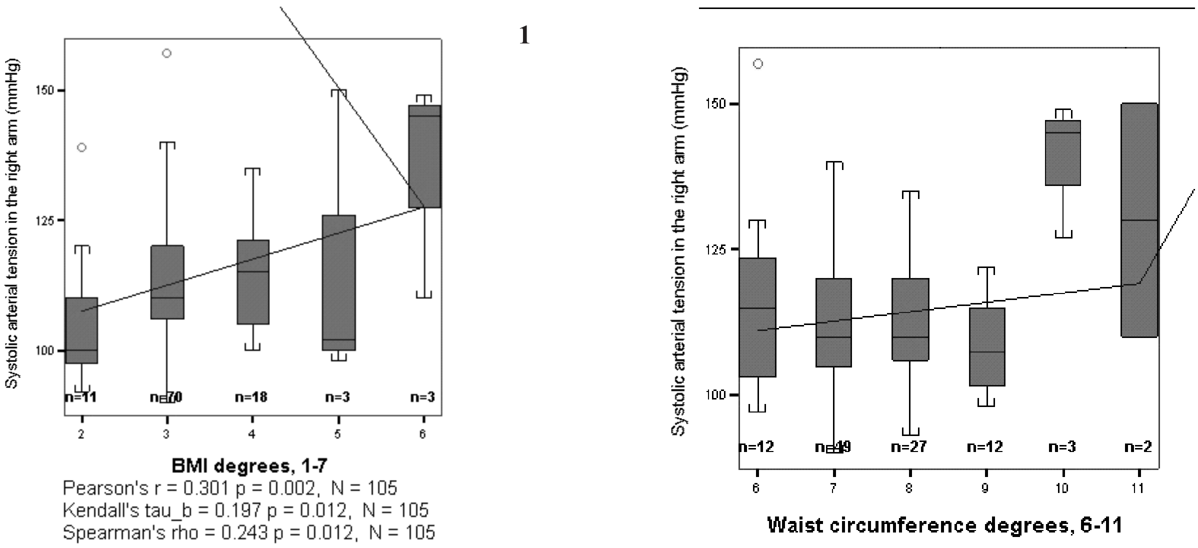


Fig. 1. Relationship between systolic arterial tension in the right arm (mmHg) and BMI (1) and waist circumference (2).

Diastolic arterial tension

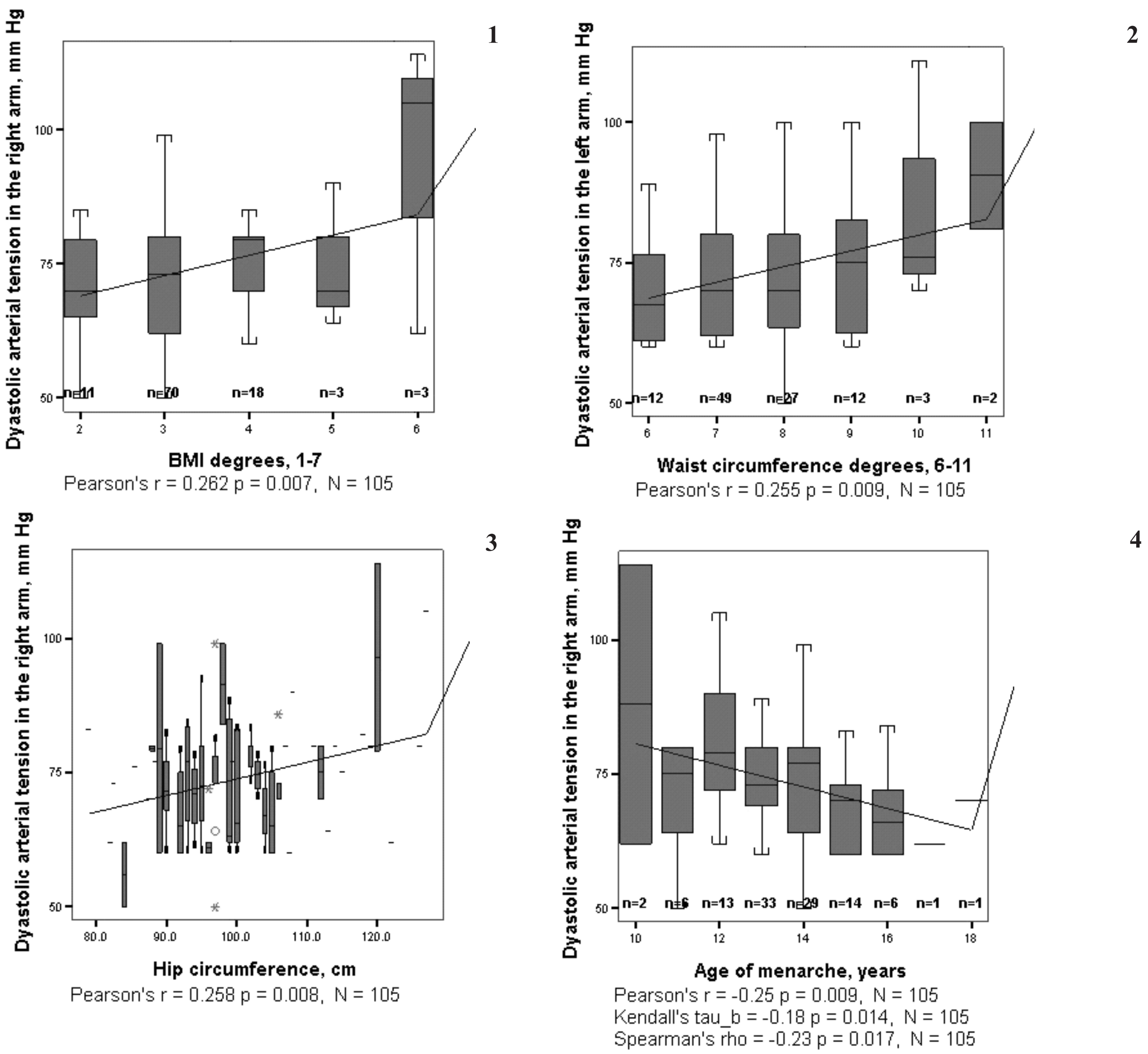


Fig. 2. Relationship between diastolic arterial tension in the right arm (mmHg) and BMI (1), waist circumference (2), hip circumference (3), and onset of menarche (4).

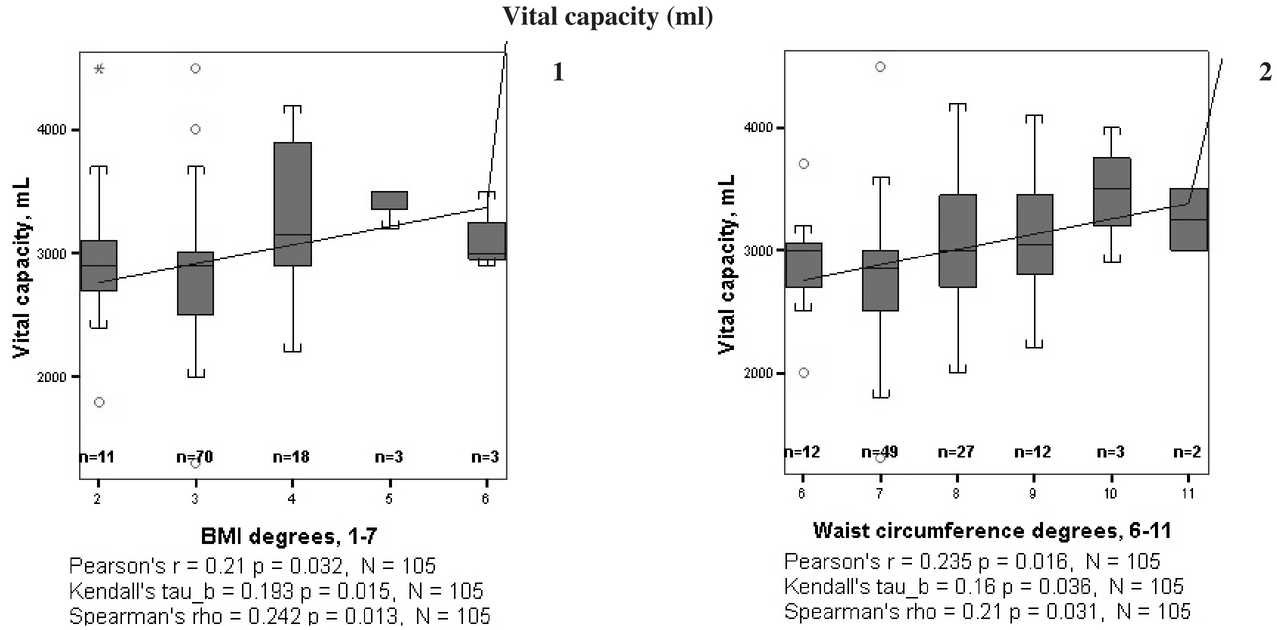


Fig. 3. Relationship between vital capacity (ml) and BMI degrees (1) and waist circumference (2).

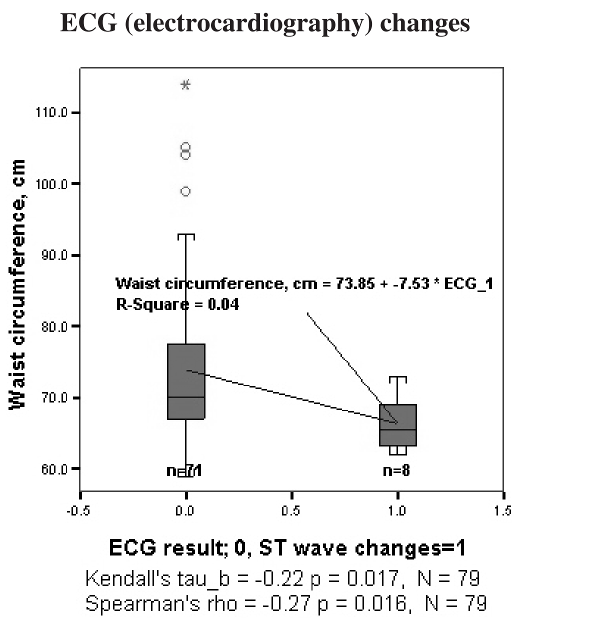


Fig. 4. Relationship between change in ECG (electrocardiography) and waist circumference (1) and ST wave changes.

cm) had lower vital capacity than three students with the I degree of obesity and increased waist circumference (96 cm). The first three students might be at risk for future breathing and cardiovascular problems.

Glucose tolerance disorders. Glucose intolerance is one of the major components of metabolic syndrome, which is associated with insulin resistance, diabetes mellitus and cardiovascular diseases (Kaplan *et al.*, 1989; De Fronzo *et al.*, 1991). Large-scale studies have show that glucose metabolic disorders, regardless of metabolic syndrome, increase carcinogenic risk in women more than in men (Stocks *et al.*, 2009). In our study, glucose concentration in blood was within the normal range and was correlated with BMI and waist circumference. Thus, the study shows that young women 18 to 25 years of age with overweight and I and II degree of obesity fit in the large scheme of symptoms of metabolic syndrome and that they may be in a risk group for serious health problems in the future.

ECG changes. Significant ECG changes (ST segment) were found in 8 of 79 students. Increased waist circumference was associated with ECG changes. This indicates that visceral obesity is closely correlates with cardiovascular changes in young women. Visceral obesity and insulin resistance are the main risk factors for metabolic syndrome (Grundy *et al.*, 2005). Localisation of ectopic fat promotes secretion of adipokines (also adiponectin) causing chronic inflammation and endothelial dysfunction (Steinberger *et al.*, 2009; Potenza *et al.*, 2009) and facilitates the manifestation of cardiovascular diseases.

Adiponectin. Adiponectin concentration correlated with arterial pressure and pulse frequency, which can be explained by a compensatory mechanism of the cardiovascular system. The increase in adiponectin concentration could be related to the subject age (Kizer *et al.*, 2011; Nishimura *et al.*, 2009). There are studies in the literature showing that adiponectin has an additional role in the normalisation of blood pressure in young people (Lambert *et al.*, 2009). Cardioprotective properties and reduction of risk to develop type 2 diabetes mellitus by adiponectin are being extensively studied at present (Li *et al.*, 2009; Hopkins *et al.*, 2007; Wang *et al.*, 2008), and the mechanisms have been explained by the effect of adiponectin on size of lipoprotein particles, regardless of the degree of obesity or insulin resistance (Weiss *et al.*, 2009).

More and more studies are now appearing in the literature on the role of genetic factors in the pathogenesis of metabolic syndrome (Grundy, 2005; Terán-Garcia *et al.*, 2007;

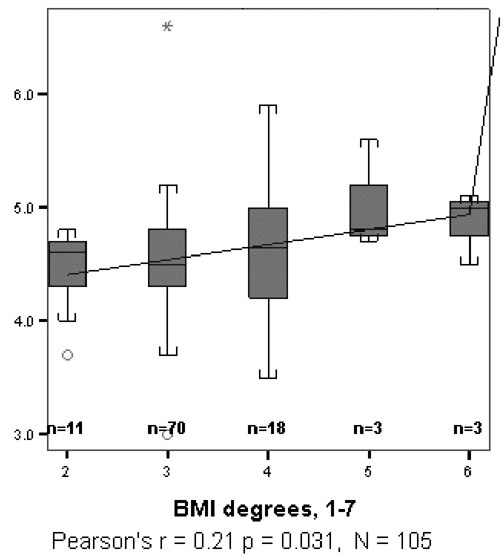
Table 2

MEASURES OF VARIABLES IN RELATION TO BMI (sugar in blood, TSH, thyroxine, adiponectin)

BMI degrees	Statistical descriptives	BMI, kg/m2	Waist circumference, cm	Sugar in blood, mmol/L	TSH, mlU/L	Thyroxine, pmol/L	Adiponectin, mg/mL
Total	N	105	105	105	105	105	38
	Mean	22.7080	74.452	4.567	1.552	15.778	22.445
	SEM	0.40696	1.0192	0.0482	0.0746	0.1669	1.2850
	Minimum	17.51	59.0	3.0	0.5	11.4	8.5
	Maximum	39.55	114.0	6.6	3.7	20.8	33.3
16.500–18.499	N	11	11	11	11	11	5
	Mean	17.9291	66.500	4.464	1.375	16.673	18.100
	SEM	0.10299	1.3568	0.1064	0.1997	0.6065	3.4486
	Minimum	17.51	62.0	3.7	0.7	14.1	9.8
	Maximum	18.44	77.0	4.8	3.0	20.1	29.7
18.500–24.999	N	70	70	70	70	70	26
	Mean	21.3390	70.957	4.524	1.594	15.720	23.738
	SEM	0.19033	0.7373	0.0567	0.0948	0.1988	1.5475
	Minimum	18.83	59.0	3.0	0.5	11.4	8.5
	Maximum	24.82	85.0	6.6	3.7	20.8	33.3
25.000–29.999	N	18	18	18	18	18	5
	Mean	27.1967	84.111	4.667	1.382	15.300	20.100
	SEM	0.37755	1.5401	0.1469	0.1558	0.3764	2.4700
	Minimum	24.97	74.0	3.5	0.5	11.4	14.4
	Maximum	29.94	98.0	5.9	3.2	17.2	26.3
30.000–34.999	N	3	3	3	3	3	
	Mean	30.4867	96.000	5.033	1.933	15.133	
	SEM	0.10682	4.5826	0.2848	0.5487	0.2963	
	Minimum	30.30	90.0	4.7	1.0	14.7	
	Maximum	30.67	105.0	5.6	2.9	15.7	
35.000–39.999	N	3	3	3	3	3	2
	Mean	37.4633	105.667	4.867	1.867	17.367	22.350
	SEM	1.22142	4.4096	0.1856	0.5783	1.0868	10.9500
	Minimum	35.32	99.0	4.5	1.1	15.2	11.4
	Maximum	39.55	114.0	5.1	3.0	18.6	33.3

SEM, Standard Error of the Mean

Glucose in the blood



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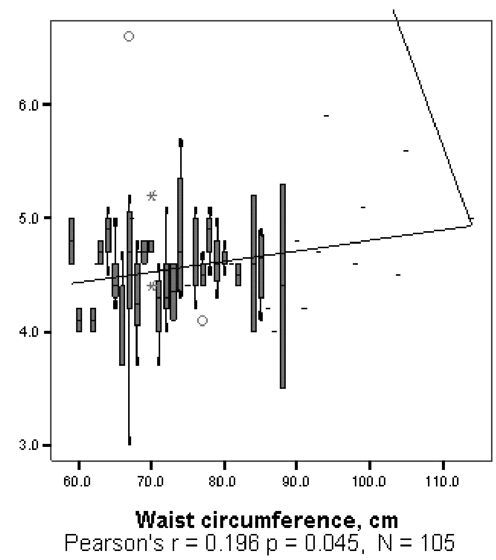

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Fig. 5. Relationship between glucose in the blood and BMI (1) and waist circumference (2).

Adiponectin

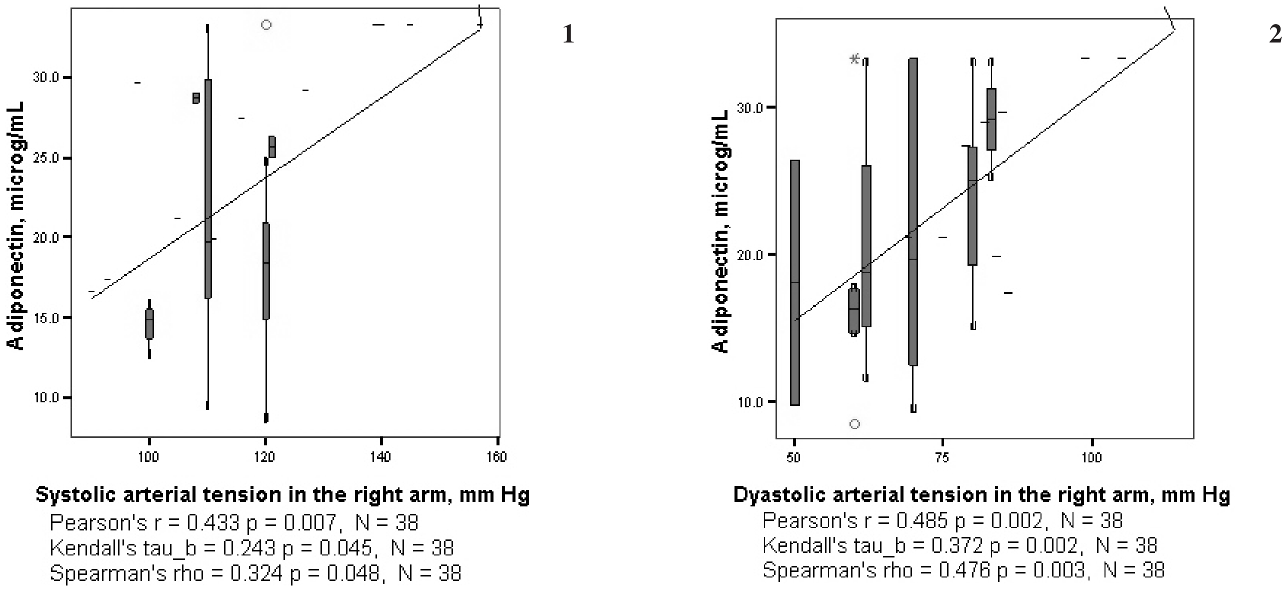
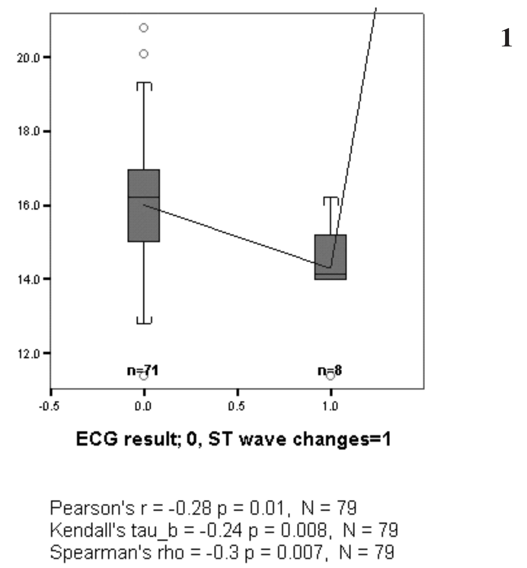
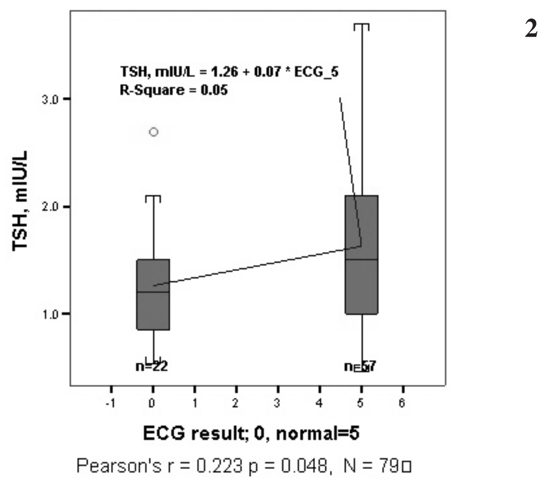


Fig. 6. Relationship between adiponectin concentration and systolic (1) and diastolic (2) arterial tension in the right arm.

Correlation of ECG





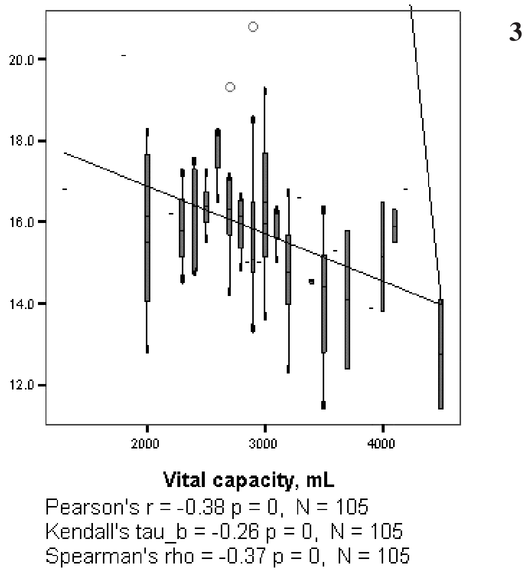


Fig. 7. Relationship of ECG changes and free thyroxine (FT4) and thyroid-stimulating hormone (TSH) concentrations (Fig. 7.1 and 7.2). Relationship between vital capacity and FT4 (Fig. 7.3)

Garaulet *et al*., 2009; Steingerger *et al*., 2009; Bruce *et al*., 2009).

Thyroid hormones. Thyroid hormones — free thyroxine (FT4), thyroid-stimulating hormone (TSH) and free triiodothyronine (FT3) cause weight changes. Weight gain has been linked with subclinical thyroid disease, which is related both to insulin resistance (Brenta 2011) and increases in TSH and T3 (triiodothyronine) concentrations (Reinehr, 2012).

The rise in TSH levels in students with I and II degree of obesity indicates the role of thyroid hormones in regulation of metabolism. In our study, thyroxine and TSH concentrations were closely related to ST-segment changes of the ECG.

Our study clearly showed correlation between arterial blood pressure and both BMI and waist circumference in students. The rise in DBP in students was also associated with increase of the hip circumference and age of onset of menarche. The blood glucose concentration was also closely associated with BMI and waist circumference. In contrast, an increase in adiponectin in women aged 18 to 25 years was associated with cardiovascular indicators (DBP and SBP, pulse frequency), but was not associated with an increase in BMI and waist circumference. Changes in thyroid function were related to the ECG ST-segment abnormalities. Thus, the main risk factors of metabolic syndrome and their relationships can already be observed in young women aged 18 to 25 years.

Increase of systolic and diastolic blood pressure, as well as increase in blood glucose concentration are closely associated with both BMI and waist circumference. These findings shoud be kept in mind when considering the importance of both factors in the pathogenesis of metabolic syndrome and arterial hypertension in young women. Changes in adiponectin and ECG are linked to an increase in waist circumference, and changes in thyroxin and TSH levels. An increase in diastolic blood pressure is related to student age at onset of menarche, indicating a possible role for genetic factors and the endocrine system in the pathogenesis of the matabolic syndrome.

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METABOLĀ SINDROMA RISKA FAKTORU IZVĒRTĒJUMS STUDENTĒM

Studentēm, kuru vidējais vecums ir 20,7 gadi, skaidri iezīmējas pozitīva sakarība starp arteriālā spiediena, ķermeņa masas indeksa (ĶMI) un vidukļa apkārtmēra palielināšanos. Vidējais sistoliskais (SAS) un diastoliskais asinsspiediens (DAS) studentēm ir optimāls (SAS 113,54 ± 1,26; DAS 73,57 ± 1,09). SAS cieši korelē ar ĶMI pakāpēm (P = 0,02–0,012) un vidukļa apkārtmēru (P = 0,002–0,02). DAS cieši korelē ne tikai ar ĶMI (P = 0,007) un vidukļa apkārtmēru (P = 0,009), bet arī ar gūžu apkārtmēra palielināšanos (P = 0,008). Būtiska ietekme uz DAS palielināšanos ir vecumam, kad iestājas *menarche* (P = 0,009–0,017). DAS ir augstāk studentēm, kuras ir jaunākas *menarche* iestāšanās laikā. Sakarība varētu norādīt par ģenētisko faktoru un endokrīnās sistēmas lomu DAS regulācijā. Plaušu vitālā kapacitāte studentēm palielinās ciešā saistībā ar ĶMI (P = 0,013–0,032) un vidukļa apkārtmēra (P = 0,016–0,032) palielināšanos. Glikozes koncentrācijas palielināšanās asinīs ir cieši saistīta ar ĶMI (P = 0,03) un vidukļa apkārtmēra (P = 0,0045) palielināšanos. Turpretī adiponektīna koncentrācijas izmaiņas ir saistītas ar sistoliskā (P = 0,007–0,048) un diastoliskā (P = 0,002–0,003) arteriālā spiediena palielināšanos, kas liecina par abu rādītāju atšķirīgiem regulācijas mehānismiem. EKG izmaiņas novērojamas 33% (26 studentēm no 79) gadījumu, bet EKG ST segmenta izmaiņas novērojamas 10% gadījumu, kas liecina par nopietnām sirds asinsvadu izmaiņām jaunām sievietēm, kuras korelē ar vidukļa apkārtmēra palielināšanos (P = 0,016-0,017).